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THERMAL PROCESSES FOR HAZARDOUS WASTE: THE EPA RESEARCH PROGRAM

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The results of the research program to date have shown that, in general, properly operated, high temperature processes can attain EPA standards for destruction and removal of organics contained in the tested hazardous waste (destruction and removal efficiency (DRE) greater than 99.99%). Effective control (99% removal) of hydrogen chloride (HCl) emissions was also attained in the facilities burning chlorinated organic waste. While technically believed achievable, the EPA standard for particulates (180 mg/dry m^3) was the most difficult to achieve in practice. Several of the tested facilities contained particulates in the stack gas at significantly higher concentrations requiring either change in operating procedures and/or improved air pollution control equipment.

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ABSTRACT

The Environmental Protection Agency (EPA) has been conducting an extensive research program to study the practice of destroying hazardous waste in high temperature industrial processes. These studies have encompassed processes such as hazardous waste incineration, and processes cofiring hazardous waste such as industrial boilers, kilns, furnaces, and asphalt plants.

The results of the research program to date have shown that, in general, properly operated, high temperature processes can attain EPA standards for destruction and removal of organics contained in the tested hazardous waste (destruction and removal efficiency (DRE) greater than 99.99%). Effective control (99% removal) of hydrogen chloride (HCl) emissions was also attained in the facilities burning chlorinated organic waste. While technically believed achievable, the EPA standard for particulates (180 mg/dry m^3) was the most difficult to achieve in practice. Several of the tested facilities contained particulates in the stack gas at significantly higher concentrations requiring either change in operating procedures and/or improved air pollution control equipment.

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BACKGROUND

Properly designed and operated thermal destruction systems offer the prospect of destroying the hazardous organic components of waste streams while reducing waste volume and, in some instances, recovering energy or materials such as hydrochloric or sulfuric acid. Because of this, thermal destruction systems have emerged over the past decade as an increasingly desirable alternative to the more traditional hazardous waste disposal methods of landfilling, lagooning, and deep well injection (1).

However, improper design and operation of thermal hazardous waste destruction systems may also pose a threat to public health through emissions of potentially hazardous components of the waste or their combustion by-products. It was the recognition of the inherent environmental advantages of waste thermal destruction, balanced against the potential problems of improper design and operation that lead the EPA to develop performance standards and permit requirements for thermal destruction systems under the Resource

Conservation and Recovery Act of 1976 (RCRA). Standards for incinerators have been in place since June 1982 and standards are currently under development for disposal of hazardous wastes in industrial processes.

It is anticipated that thermal destruction will become even more important in the future as EPA responds to the U.S. Congressional mandate to restrict many hazardous wastes from land disposal and to effect corrective action at abandoned and uncontrolled disposal sites under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Of the many thermal processes in various stages of development in the country today, there are only five technologies that have been used to treat significant amounts of hazardous waste. These are liquid injection incinerators, rotary kiln incinerators, industrial boilers, cement kilns, and ocean incinerator ships.

Definitions

Thermal destruction of hazardous waste involves the controlled exposure of waste to high temperature (usually 900°C or greater), and typically, an oxidizing environment. Thermal destruction processes include: thermal oxidation, starved air, or pyrolytic incineration systems; high temperature industrial processes such as boilers, cement kilns, and industrial furnaces where hazardous waste is employed as a fuel; and various emerging processes which employ high temperatures, such as molten salt, molten glass, plasma-arc electric furnaces, etc.

The three performance standards that the EPA is using for determining the satisfactory performance of high temperature, hazardous waste destruction processes are DRE, HCl removal and particulate emissions. Standards also exist (or are in process of being established) for the liquid and/or solid residuals from these processes. The details of what rules apply for identifying, handling and disposing of these residuals will not be discussed here other than to point out that there is significant activity within the EPA in the residuals area. This activity is both at the research and regulatary level. During EPA research activities these residuals were sampled and analyzed.

The DRE is the basic measurement of process efficiency and is determined by comparison of inlet and outlet concentrations of certain specified organic constituents, identified by the RCRA regulatory language as POHCs (Primary Organic Hazardous Constituents). A number of POHCs are determined by the EPA permitting official in reviewing a permit application from a hazardous waste destruction facility. The POHCs are chosen on the basis of those organics present in the highest concentrations in the waste (allowing for best resolution of DRE) in combination with those being considered the most difficult to destroy. The use of the POHC system avoids the requirement for determining all species of organics going into, and coming out of the thermal destruction device by the assumption that if the highest concentrations of the most difficult organics are reduced to acceptable levels, the remainder will be also.

The DRE is determined using the following equation:

$$DRE\ percent = (Win - Wout)/Win \times 100$$

Where: Win = Mass feedrate of a POHC in the waste stream to the process

Wout = Mass emission rate of the POHC in the exhaust stack prior to release to the atmosphere.

The required minimum DRE for most hazardous organics (POHCs) is 99.99 percent (also known as fourmomrd). In the case of certain organics considered highly toxic (such as, for example polychlorinated biphenyls (PCB's), chlorinated dioxins and furans) the requirement is for six nines DRE (99.9999).

The HCl performance requirement specifies 99 percent removal from the exhaust gas if the HCl emission rate is greater than 1.8kg/hr.

Particulate emissions are to be no greater than 180 mg/standard, dry, M^3 for airflow that is corrected to seven (7) percent oxygen in the stack gas prior to release to the atmosphere.

Survey Results

The most recent complete data on hazardous waste thermal destruction practices come from EPA surveys of industry activity in 1981 (2). Table 1 shows a summary of this data. EPA has estimated that the United States generated 264 million metric tonnes (MMT) of hazardous waste in 1981. A significant portion of this waste was predominently non-hazardous material (water, inorganics, etc.) contaminated with hazardous materials. While only a relatively small amount of hazardous waste was managed by thermal destruction (Table 1), EPA estimated that as much as 25 MMT per year could have been thermally destroyed. In reality, the organic portion of virtually any waste material is amenable to thermal destruction. Thus, considerably more waste could have been directed to thermal destruction processes than the 25 MMT/yr estimate (3).

It is also significant to note that more than twice as much hazardous waste was burned in industrial processes as fuel, as compared to that disposed in specially designed incineration systems.

Table 1 - Hazardous Waste Thermal Destruction Facilities (1981)

Thermal Destruction Facility	Waste (MMT/yr)*	Major Waste Types (by volume)
Incinerators (240 facilities)	1.70	Non-halogenated solvents, corrosives, reactive wastes
Industrial Boilers (1300 facilities)	3.50	Organic solvents, ignitable wastes
Other (kilns, etc.)	0.35	Organic solvents
	5.55	

*MMT/yr = million metric tonnes per year

Since the survey of the year 1981 (which was performed during the 1983-84 time period), significant efforts are underway to determine capacities of various treatment and disposal methods. These efforts are to provide data for determining exceptions to be 1984 Hazardous Solid Waste Amendment (HSWA) to RCRA. The amendment requires the exclusion of hazarrdous waste from land disposal unless insufficient capacity exists. One study, to determine incinerator and kiln capacities for destruction of hazardous waste, has been recently completed (4). This study updates incinerator capacity by general type of unit, and determines available capacity by comparing design capacity and present utilization. A summary of these findings are presented in Table 2. The available capacity of 2530 million BTU/hour at an average waste heating value of 8580 BTU/lb translates into approximately one million metric tonnes per year. Other results from this study showed that the total number of active hazardous waste incinerators have decreased somewhat from the 1981 survey (estimated at 230 to 240 in 1981, only 208 units in 1985). Additionally, of 57 companies identified in 1981 as being in the hazardous waste incinerator business, 23 have gone out of business, left the hazardous waste area or put much less emphasis on this activity (4). Only one new company has joined the market.

Cement kiln capacity was less easily determined. Potential capacity for this study was determined by assessing three levels of fuel replacement by waste and assuming three levels of waste heating values. This information is summarized in Table 3.

TABLE 2 - ESTIMATION OF AVAILABLE INCINERATOR CAPACITY BY INCINERATION DESIGN (1985)

INCINERATOR DESIGN	NUMBER OF UNITS	AVERAGE DESIGN CAPACITY PER UNIT (Million Btu/hr)	UTILIZATION (Percent)	AVAILABLE CAPACITY (Million Btu/hr)	PERCENT WITH AIR POLLUTION CONTROL EQUIPMENT
Rotary Kiln	42	58.7	77	570	90
Liquid Injection	95	36.1	55	1540	42
Fume	25	29.5	94	40	40
Hearth	32	22.5	62	270	38
Other	14	23.8	--	110	--
Total or Average Values	208	37.6*	67**	2530	50

* 181 incinerators reporting
** 90 incinerators reporting

TABLE 3 - ESTIMATED CEMENT KILN WASTE CAPACITY (1985)

Fuel Replacement Rate (Percent)	Waste Heating Value (Btu/lb)	Annual Cement Kiln Waste Capacity (Million of Metric Tonnes per Year)
10	8,000	2.27
30	12,000	4.54
60	18,000	6.05

PERFORMANCE TEST RESULTS

Since 1980, the Office of Research and Development (ORD), the Office of Water (OW), and the Office of Solid Waste (OSW) have cooperated in conducting performance tests of over 40 full-scale hazardous waste thermal destruction facilities in the United States. The data from these tests have been utilized extensively in defending current Resource Conservation and Recovery Act (RCRA) regulations and standards, in developing proposed standards and in preparing Regulatory Impact Analysis (RIA) related to hazardous waste thermal destruction. These boilers, and cement kilns are capable of achieving or exceeding 99.99 percent Destruction and Removal Efficiency (DRE) of the principal organic hazardous constituents (POHCs) in hazardous wastes. All facilities tested usually attained the RCRA standard for removal of hydrochloric acid (HCl) from stack emissions. OSW conducted risk assessments of the emissions from incinerators tested by ORD and concluded in their RIA that residual organic compounds posed no sigfnificant health risk.

Summaries of Test Data

Tables 4, 5, 6 & 7 describe the facilities and waste types encompassed by the test program and summarize waste destruction and emission performance data. All of the incinerator tested achieved 99.99 percent DRE for candidate POHC compounds in concentrations greater than 1000 parts per million (ppm) in the waste feed. Candidate POHC compounds below 500 ppm were not always destroyed to the 99.99 percent level. This phenomenon, which was also observed in tests of other thermal destruction devices, was unexpected. A number of possible explanations have been advanced.

To demonstrate 99.99 DRE at very low POHC concentrations (less than 500 ppm), stack emission concentrations of less than 50 parts per billion (ppb) have to be measured. Sampling and analysis techniques may be the limiting factor, skewing these measurements toward higher readings in some cases.

Also, at these low emission levels, sufficient amounts of POHC may actually be formed as an incomplete combustion or recombination by-product of other organics or materials in the wastes which in sum produces less than 99.99 percent DRA.

EPA is conducting research to further assess this concentration effect phenomenon. From a regulatory standpoint, however, this is not currently perceived as a problem since few if any of the low concentration compounds in the wastes identified in the EPA test program would have actually been selected as POHCs in trial burns, if the existing EPA guidance on POHC selection were employed. Cement kilns, lime kilns, and light weight aggregate kilns with adequate combustion control and waste atomization all met or exceeded the 99.99 percent DRE. It is also important to note that for all of the incinerators and industrial processes tested, the destruction (D) and the removal (R) efficiencies observed were due to destruction rather than removal or capture of hazardous organics. Ash, scrubber water, and air pollution control device residues were typically below detection limits for POHCs and organics in general. All incinerators and industrial process kilns tested met or approached the RCRA HCl removal standard. Industrial boilers typically have no existing controls for HCl, but none exceeded the 1.8 Kg/hr (4 lb/hr) emission standard since wastes with low net chlorine content were employed (6).

TABLE 4 - INCINERATOR PERFORMANCE AND STACK EMISSIONS DATA

FACILITY TYPE	O_2 (%)	CO (ppm)	THC (ppm)	DRE(a) (NUMBER OF NINES)	PARTICULATE (mg/m^3)	HCl CONTROL
(1) Commercial Rotary Kiln/ Liquid Incinerator	10.5	<1.0-14.8	<1.0	5.3	1508	99.4%
(2) Commercial Fixed Hearth, Two Stage Incinerator	11.4	4.7 9.1	1.0	4.4	400	98.3%
(3) On-site Two-Stage Liquid Incinerator	8.3	9.9-11.2	3.9-8.9	4.4	61	99.7%
(4) Commercial Fixed Hearth, Two-Stage Incinerator	11	7.5 22.2	<1.0 1.9	4.7	200	<1.8 kg/hr
(5) On-Site Liquid Injection	12.1	6.7 19.3	<1.0	6.7	207	<1.8 kg/hr
(6) Commercial Two-Stage	9.9	<1.0 1.8	<1.0	4.8	900	<1.8 kg/hr
(7) On-Site Rotary Kiln	9.7	422-666	47.6-75.9	5.3	23	99.9%
(8) Commercial Two-Stage Fixed Hearth Incinerator	13.6	0.9-4.3	0.8-2.5	4.6	169	98.3%

(a) mass weighted averages for all POHCs >100 ppm in waste
4.5 nines = 99.995% DRE

TABLE 5 - SUMMARY OF STEADY-STATE BOILER PERFORMANCE (6)

Facility Type	Load (%)	O_2(%)	Residence Time (sec)	Average Volumetric Heat Release Rate KW//m^3	DRE[d] (No. Nines)	W/F[a] (%)	NO_x[b] (ppm)	CO[b] (ppm)
(1) Watertube Stoker	100	6-16	1.2	509	3.8	40	163-210	900-1200
(2) Packaged Firetube	25	4-6	0.8	739	4.1	0.1-05	40-65	47-88
(3) Field Erected Watertube	26	10	2	78	5.6	37	61-96	18-21
(4) Converted Stoker	78	4-6	1.1	339	4.8	18-48	193-250	75-127
(5) Packaged Watertube	36-73	6-7	0.5-1.1	960	4.5	19-56	164-492	83-138
(6) Converted Watertube	53	7-11	2	107	3.8	8.7-10.1	243-328	109-139
(7) Modified Firetube	44	8	0.4	807	4.8	100	67-74	146-170
(8) Tangentially Fired Watertube	100	6	2	180	4.1	2.4-4.3	393-466	142-201
(9) Packaged Watertube	65	2	1.8	343	4.8	8.2	64-78 410-1125[c]	46-750
(10) Packaged Firetube	50-100	3-8	0.3-0.7	1240	5.0	100	85-203	20-135
(11) Packaged Watertube	82	4	1.8	269	5.7	49	154-278	102-119

(a) W/F = waste heat input as a % of total heat input
(b) range of average values across individual sites and runs including baseline
(c) higher values are for high nitrogen waste firing
(d) DRE = destruction and removal efficiency (e.g., 4.5 nines = 99.995% DRE)

TABLE 6 - SUMMARY OF NONSTEADY-STATE BOILER PERFORMANCE

Test Site	Facility Type (Steam Capacity)	Primary Fuel	Cofired (a) waste	Injected (b) POHCs	Transient Conditions, Ranges Tested			
					Load (%capacity)	O_2 (%excess)	W/F(c) (%)	DRE (%)
L	Watertube, Forced Draft, 1 Burner (14kg/S or 110 lb/hr x10^3)	Oil and/or natural gas	MMA-TSB	CCl_4, MCB	23-70	1-8	7-56	99.998
M	Watertube, Forced Draft 4 Burners (44kgs/or 350 lb/ hrx10^3)	Natural gas	Butanol/ Propanol Oil	CCl_4, MCB, TCB	35-56	1-10	20-30	99.9991
N	Watertube, Balanced Draft, Stocker (19kgs/or 150 lb/ hrx10^3)	Stocker coal and No. 2 oil	Wastewater sludge	TCE, TCB Chromium Lead	53-90	5-12	0-35	99.996

(a) Cofired wastes: MMA-TSB Methylmethacrylate, Third Stage Bottoms

(b) Injected POHCs: MCB Monochlorobenzene
TCB 1, 2, 4 Trichlorobenzene
TCE Trichloroethylene

(c) W/F Percent of total heat input provided by waste fuel

TABLE 7 - SUMMARY OF INDUSTRIAL KILN PERFORMANCE (6)

FACILITY TYPE	TEST[a]	DRE[b] (NO. NINES)	PARTICULATES[d] (kg/Mg)	HCl (kg/hr)	NO_x (ppm)	SO_2 (ppm)	W/F(%)(C)
(1) Wet Process Cement Kiln (Non-atomized Waste)	W	2.2	.27	.36	68	450	25
	B	-	.26	.09	136	279	-
(2) Wet Process Cement Kiln (Atomized Waste)	W	4.6	.27	2.1	478	265	15
	B	-	.26	.6	371	636	-
(3) Dry Process Cement Kiln (Non-atomized Waste)	W	4.8	-	11.5	814	19	45
	B	-	-	1.3	620	7	-
(4) Dry Process Cement Kiln (Atomized Waste)	W	4.2	-	.47	486	27	15
	B	-	-	.25	680	27	-
(5) Lime Kiln (Atomized Waste)	W	4.7	.11	.20	446	596	30
	B	-	.10	.09	386	553	-
(6) Shale Aggregate Kiln (Atomized Waste)	W	>4.0	.33	2.1	-	-	100
(7) Clay Aggregate Kiln (Atomized Waste)	W	4.8	0.58	0.023	162	1130	59
(8) Clay Products Kiln (Atomized Waste)	W	>4.0	.002	0.84	-	-	100

(a) W = waste testing, B = baseline (no waste firing)

(b) DRE = destruction and removal efficiency (e.g., 4.5 nines = 99.995%)

(c) % of total heat input provided by waste fuel

(d) Stack emissions of particulate matter expressed as kg of emission per Mg of clinker produced

Achieving the particulate emission standard was a problem for a number of the incinerators tested. In one test program, four of the eight units failed to meet the RCRA standard. Two of those facilities were marginally above the emission limit. They might be likely to meet the standard with minor operating adjustments or with other state-of-the-art control devices added. The remaining two facilities appeared to need significant design and/or operational changes.

This general trend is consistent with the results of RCRA permit trial burns conducted for other incineration facilities over the past two years. No significant changes in particulate emissions were observed for industrial boilers and certain of the industrial process kilns when they fired RCRA waste fuels. Some increased emissions were observed in kilns employing electrostatic precipitators (ESP) for particulate control. These increases were attributed to changes in the electrical resistivity of the particles due to the presence of increased chloride levels. Adjustments in ESP operation might correct this in most cases.

Products Of Incomplete Combustion (PICs)

The current RCRA standards regulate destruction and removal only for the major hazardous compounds in the waste. Under poor combustion conditions, many compounds may only partially decompose and form products of incomplete combustion (PICs) which are also hazardous compounds of concern if emitted. For the purpose of the EPA test program, compounds were considered to be PICs if they were regulated organic compounds (i.e., listed in Appendix VIII of CFR 40 Part 261) (7) which were detected in stack emissions, but not present in the waste feed at concentrations greater than 100 ppm. The PICs most frequently identified in the EPA testing of incinerators and industrial boilers at steady-state were benzene, chloroform, and tetrachloroethylene (Table 8). Data from a test series of three sites testing boilers at nonsteady-state is in process of being analyzed. While the types of PIC's observed for this test series are generally the same as those for steady-state, specific levels have not been determined at this writing. One significant trend that has been observed for both series of boiler tests was that the PIC/POHC ratio, which has generally observed at near unity for the incinerator tests, was significantly larger. An average value of 30 was determined for the steady-state tests and a value of approximately 5 was determined for the nonsteady-state series (8). Detailed PIC analyses have been completed for only three cement kiln tests. The most common PICs identified during the kiln tests were benzene, benzaldehyde, toluene, and various naphthalenes.

Analysis Of The Pooled Data

The incinerator test program revealed that there was no narrow band or finite level of mean combustion temperature, mean gas phase residence time or carbon

TABLE 8 - PICs MOST FREQUENTLY DETECTED IN STACK EMISSIONS (5)

	NUMBER OF FACILITIES	CONCENTRATION (ng/l)
Incinerators		
Benzene	6	12-670
Chloroform	5	1-1,330
Bromodichloromethane	4	3-32
Dibromochloromethane	4	1-12
Naphthalene	3	5-100
Bromoform	3	0.2-24
Chlorobenzene	3	1-10
Tetrachloroethylene	3	0.1-2.5
1,1,1-Trichloroethane	3	0.1-1.5
Toluene	2	2-75
o-Nitrophenol	2	25-50
Methylene Chloride	2	2-27
Phenol	2	4-22
Boilers (a)		
Chloroform	5	4.2-1900
Tetrachloroethylene	5	0.3-760
Chloromethane	4	4.6-410
Methylene chloride	4	83-2000
Benzene	3	9.4-270
1,1,1-Trichloroethane	3	5.9-270
1,2-Dichloroethane	3	1.3-1200
1,1-Dichloroethylene	2	0.21-38
1,1,2,2-Tetrachloroethane	2	4.6-16
Toluene	2	46-960

(a) excluding nonsteady state test data which is incomplete at this time.

monoxide emission concentration which correlated with achieving 99.99 percent DRE. Residence times ranged from 0.1 to 6.5 seconds in the facilities tested. Temperatures ranged from 648°C to 1450°C. Carbon monoxide (CO) levels were as high as 600 ppm, but at most plants ranged from 5 ppm to 15 ppm (6). It appears to EPA at this time that the relationships between DRE and these parameters are in all likelihood facility specific and that waste characteristics, waste atomization, and combustion chamber mixing likely play an equally important role in achieving high DRE. Timing, funding, and facility constraints did not allow for colletion of sufficient performance data under varying conditions at each site tested to allow for such relationships to be quantified. EPA is continuing to add new test results and information from permit trial burns and from testing at EPA pilot-scale and full scale research facilities to the data base in an effort to better predict DRE from process parameters.

FUTURE WORK

Prospects For Thermal Destruction

The prospects for increased utilization of thermal destruction processes for hazardous waste disposal are significant. Incineration is considered a proven, commercially-available technology which has been demonstrated to be suitable for accommodating a wide range of organic wastes. Industrial high-temperature processes also can be suitably modified to destroy certain types of hazardous wastes (particularly combustible liquids) while recovering energy.

Thermal destruction is currently used to manage only about 2 percent of hazardous wastes generated annually. Many of the remaining wastes are being directed to land disposal facilities. However, the recently promulgated Hazardous and Solid Waste Amendments of 1984 (RCRA Amendments), with their sweeping provisions to restrict many wastes from land disposal, will prompt more intense consideration of thermal destruction as a control option. If it is assumed that the regulations are implemented immediately and current incineration capacity does not increase at the same time, a number of demand distributions, beyond existing capacity, can be estimated, as shown in Table 9.

TABLE 9 - Excess of Demand Over Existing Incineration Capacity (expressed as a % of current capacity) (9)

Regulatory Scenario	On-site[a]	Off-site[b]
-Landfill Restrictions	40%	215%
-Deep Well Injection Restrictions	54%	306%
-Disposal Impoundments Prohibitions	52%	288%
-Waste-In-Boilers Restrictions	42%	106%

[a] Facilities on company land accepting only waste generated by that company "on-site."

[b] Facilities whose primary purpose is to accept wastes from numerous generators.

Additional listings of hazardous wastes and lowering the small generator exemption (also part of the RCRA amendments) could have further effects on the demand for incineration. However, these are not projected in this analysis.

Using the projections of excess demand for commercial incineration created by the four regulatory changes, estimations of incinerator equivalents that would be required in order to meet such demand can be drawn. Such projected excess demand could be met by either 82 additional land-based incinerators (20,000 metric ton per year average capacity), or 33 additional incinerator ships (50,000 metric ton per year average capacity) (8).

Kilns and other high temperature industrial processes have a significant potential capacity to dispose of hazardous waste which will become available due to the regulatory impacts projected. The tempering effect on the willingness of owners of these facilities to accept these wastes for thermal destruction and heat recovery (in some cases) will be the degree to which the waste is suitable for the process. It is anticipated that significant amounts of the waste diverted from restricted disposal methods will have less energy value, contain a higher ash, solids and water content, and produce compatibility problems with the process and/or the process equipment. The EPA has begun concentrated effort in evaluating and defining methods of pre-treatment which could make more of the diverted waste compatible with existing high temperature industrial processes.

Permitting and siting difficulties are significant impediments to the development of commercial incinerator capacity as well as the use of various industrial processes for waste destruction. Consequently, available commercial incineration capacity is likely to grow little over the short-term. A three to five year lag-time is possible before significant new capacity could be available. Many believe that the use of mobile incinerators or larger, transportable units is one way of mitigating the public opposition which frequently plagues permanent centralized incineration facilities. While a number of mobile systems have been proposed, most are still developmental at this point. Little actual field testing has been done beyond that underway on an EPA-owned mobile rotary kiln incinerator and a similar commercial unit. The EPA unit has been tested for PCB carbon tetrachloride destruction and, most recently, the successful incineration of dioxin-contaminated soils in Missouri (5).

PROBLEMS TO BE SOLVED

Thermal destruction is a widely applicable technology for management of organic hazardous waste. Associated with the use of this technology is a slate of technical, socio-economic and political problems that need to be resolved before the technology can be fully implemented. Some of the major points that EPA is addressing are discussed in the following.

Waste Characterization and Classification. While many wastes have been well tested and characterized, many still are not. This is especially true for more complex wastes which will emerge as candidates for thermal destruction due to the new regulations. Information on pre-treatment requirements, impact on processes, "incinerability" data, emission control data and residue handling and treatment will be required.

PICs. Products of incomplete combustion or recombination need to be further tested, measured and minimized for new wastes and new processes. In previous testing, EPA has detected these compounds at concentrations similar to the residual POHCs in the stack effluents when the processes were achieving high levels of destruction efficiency. In boilers, PICs have been observed at levels one order of magnitude greater than those in incinerators. In boilers, PICs have been observed at significantly higher concentrations, in the range of one order of magnitude. The existance of PICs has created concern within the public sector. This concern has required the EPA to provide more detailed studies of PIC emissions to allay the concerns raised by this issue. These studies have taken the form of basic research, to understand the mechanisms of PIC formation, and PIC control, through optimization of combustion conditions and definition of offdesign operating envelopes that produce unacceptable levels of PICs.

Heavy Metals. The presence of heavy and toxic metals in hazardous waste creates a special problem. Metals, such as arsenic, chromium, lead, zinc, etc. are not destroyed by high temperature processes, but rather are vaporized, liberated, oxidized or recombined with the waste ingredients and discharged as ash trapped at the air pollution control equipment (as solid or liquid matter) or passed into the air.

To deal with these wastes effectively, EPA believes that pretreatment methods need to be evaluated and developed for removing the metals. Similarly, organometalic compounds (e.g. sodium cyanide, zinc-based pesticides, etc.) may be difficult to destroy and/or may result in the destruction of the organic fraction but liberation of the metallic elements. More information is needed (1).

Acutely Hazardous Waste. Additional work is needed regarding the incineration of chemical compounds considered to be "acutely" hazardous such as many of the chlorinated dioxins and furans. Although these compounds have been incinerated successfully in low concentrations to date, additional testing is required with increased detection limit capability and under varied conditions (e.g., absorbed in waste soils, in high concentrations, etc.) to build confidence that these toxic compounds can be effectively destroyed by incineration (5).

Process Monitoring. While tests at full scale facilities and trial burn tests for incinerator permit applications have shown that most thermal destruction facilities achieve required levels of organic hazardous waste destruction, off-design operation, resulting in process upsets or failure modes may result in significantly lower DREs. The EPA has placed major emphasis in the area of defining and developing engineering relationships that will provide the capability of demonstrating compliance with performance regulations. The goal is to provide a means by which process operation can be maintained within DRE limits via easy to measure continuos or near-continuos readings of process operating parameters. To date this work has demonstrated that these relationships are

more complex than hoped. It has further shown that no single operating parameter in a simple relationship will be sufficient to predict DRE information with adequate accuracy. When developed, this information will provide real time, cost effective DRE compliance data for informing plant operators and EPA enforcement officials of compliance status. Further, this information will allay the concerns of the public for the continuing safe operation of the permitted hazardous waste facilities.

Ongoing Research

The EPA's Office of Research and Development, is working closely with the Office of Solid Waste, the Office of Water, the Office of Enforcement, the Office of Toxic Substances, and the Regional Offices to address the issues surrounding the thermal destruction of hazardous waste. Performance testing is being conducted at full-scale incinerators, industrial boilers, and other industrial processes (batch asphalt plants) to assess metal emission and off-design or failure conditions. The data are to be used by the Office of Solid Waste to finalize possible metal emission standards and rules for use by industrial boilers and kilns and other processes for cofiring of hazardous waste.

A significant portion of the needed research is being conducted at EPA facilities. The Combustion Research Facility (CRF) in Arkansas houses two, fully permitted, pilot-scale incinerators which can be used to conduct controlled experiments on processes failure modes, metal partitioning, compliance monitoring methods, PIC formation, and incinerability studies on problem wastes from Superfund sites. This work is directed and optimized by the results of smaller-scale experiments in facilities in Cincinnati (Center Hill) and Research Triangle Park, North Carolina (RTP). Here bench and laboratory combustion systems are designed to isolate the significance of important thermal destruction phenomena upon process failure, performance indicator compounds and PICs. These facilities include experimental equipment to assess: waste atomization (RTP); solids decomposition and volatization (RTP); quenched flame phenomena (Center Hill); post-flame thermal decomposition/recombination (Center Hill); flame and burner and effects (Center Hill). At Edison, New Jersey, the Release Control Branch conducts programs using a mobile incinerator to test the feasibility to detroy spilled hazardous wastes. The remainder to the research is performed under contract as part of the extramural program or as Interagency Agreements (IAGs).

The conclusions drawn from the research performed to date are that the high temperature destruction of hazardous waste is an effective method of dealing with the problem if certain precautions are observed. Certain waste types (such as those containing heavy metals) are not well suited for the present technology and must be treated or pretreated by other methods. More information is needed to fill the holes within the generally explored research matrix. New methods have to be developed to deal with the pressure of new and larger amounts of wastes that will vie for high temperature destruction. Cost effective and reliable monitoring methods need to be developed that insure proper operation and convince a skeptical public that these methods are safe and, especially, safer than the alterntives.

REFERENCES

1. Oberacker, D. A. "Hazardous Waste Incineration Performance Evaluations by the U. S. Environmental Protection Agency" Paper presented at the Energy Sources and Technology Conference and Exhibition, Dalls, TX - February 17 - 21, 1985.

2. National Survey of Hazardous Waste Generators and Treatment, Storage and Disposal Facilities Regulated Under RCRA in 1981, U.S. EPA, 1984 (Available from U. S. Government Printing Office, Washington, D.C. 20402, $9.50, Order No. 055000-00239-8).

3. Draft Regulatory Analysis for Proposed RCRA Regulations on Burning of Hazardous Wastes, U.S. EPA, January 1984.

4. Vogel, G. A. et. al. "Incinerator and Cement Kiln Capacity for Hazardous Waste Treatment". Paper presented at the Twelfth Annual Hazardous Waste Symposium, Cincinnati, Ohio, April 21 - 23, 1986.

5. Stoddard, S.K. et. al. Alternatives to the Land Disposal of Hazardous Wastes: An Assessment for California. State of California Governor's Office of Appropriate Technology. 1981.

6. Oppelt, E. T. "Thermal Destruction of Hazardous Waste" Paper to be presented at the United States of America/Spain Joint Seminar On The Treatment and Disposal of Hazardous Wastes, Mandrid, Spain, May 19 - 22, 1986.

7. Federal Register, Vol. 45, No. 98, May 19, 1980, pp. 33132-3333.

8. Castaldini, Carlo, et. al. "Nonsteady-State Testing of Industrial Boilers Burning Hazardous Waste." Paper presented at the Twelfth Annual Hazardous Waste Symposium, Cincinnati, Ohio, April 21 - 23, 1986.

9. Assessment of Incineration as a Treatment Method for Liquid Organic Hazardous Wastes, U.S. EPA Office in Policy, Planning, and Evaluation. Washington, DC. March 1985.